CLAIMS

1. A method for yielding transient solutions for the film-blowing process by using a film-blowing process model characterized that the following governing equations in consideration of the viscoelasticity and cooling characteristics of the film are first solved; and then, through coordinate transformation, the free-end-point problem is changed into a fixed-end-point problem; and finally, by introducing Newton's method and OCFE (Orthogonal Collocation on Finite Elements), the transient solution for the film blowing process is obtained:

Equations:

$$\frac{\partial}{\partial t}\left(rw\sqrt{1+\left(\frac{\partial r}{\partial z}\right)^2}\right)+\frac{\partial}{\partial z}(rwv)=0 \quad ...(1)$$

Here,

$$t=\frac{\bar{t}\,\bar{v_0}}{\bar{r_0}},\ z=\frac{\bar{z}}{\bar{r_0}},\ r=\frac{\bar{r}}{\bar{r_0}},\ v=\frac{\bar{v}}{\bar{v_0}},\ w=\frac{\bar{w}}{\bar{w_0}}$$

Axial direction:

$$\frac{2rw[(\tau_{11}-\tau_{22})]+2r\sigma_{surf}}{\sqrt{1+(\partial r/\partial z)^2}}+B(r_F^2-r^2)-2C_{gr}\int_0^{z_L} rw\sqrt{1+(\partial r/\partial z)^2}\,dz-2\int_0^{z_L} rT_{drag}\,dz=T_z \quad ...(2)$$

Here,

$$T_z = \frac{\overline{T_z}}{2\pi\overline{\eta_0}\overline{w_0}\overline{v_0}},\ B = \frac{\overline{r_0^2}\Delta P}{2\overline{\eta_0}\overline{w_0}\overline{v_0}},\ \Delta P = \frac{A}{\int_0^{z_L}\pi\overline{r}^2 d\overline{z}} - P_a,\ \tau_{ij} = \frac{\overline{\tau_{ij}}\overline{r_0}}{2\overline{\eta_0}\overline{v_0}}$$

$$C_{gr} = \frac{\rho g \overline{r_0^2}}{2\overline{\eta_0}\overline{v_0}},\ T_{drag} = \frac{\overline{T_{drag}}\overline{r_0^2}}{2\overline{\eta_0}\overline{v_0}\overline{w_0}},\ \sigma_{surf} = \frac{\overline{\sigma_{surf}}\overline{r_0}}{2\overline{\eta_0}\overline{v_0}\overline{w_0}}$$

Circumferential direction:

$$B = \left(\frac{[-w(\tau_{11}-\tau_{22})+2\sigma_{surf}](\partial^2 r/\partial z^2)}{[1+(\partial r/\partial z)^2]^{3/2}} + \frac{w(\tau_{33}-\tau_{22})+2\sigma_{surf}}{r\sqrt{1+(\partial r/\partial z)^2}} - C_{gr}\frac{\partial r/\partial z}{\sqrt{1+(\partial r/\partial z)^2}}\right)$$

...(3)

Constitutive Equation:

$$K\tau + De\left[\frac{\partial \tau}{\partial t} + v \cdot \nabla\tau - L \cdot \tau - \tau \cdot L^T\right] = 2\frac{De}{De_0}D$$

...(4)

Here,

$$K = \exp[\epsilon De \operatorname{tr}\tau],\ L = \nabla v - \xi D,\ 2D = (\nabla v + \nabla v^T),\ De_0 = \frac{\lambda\overline{v_0}}{\overline{r_0}},$$

$$De = De_0 \exp\left[k\left(\frac{1}{\theta} - 1\right)\right]$$

Energy equation:

$$\frac{\partial\theta}{\partial t} + \frac{1}{\sqrt{1+(\partial r/\partial z)^2}}\frac{\partial\theta}{\partial z} + \frac{U}{w}(\theta - \theta_c) + \frac{E}{w}(\theta^4 - \theta_\infty^4) = 0$$

...(5)

Here,

$$\theta = \frac{\bar{\theta}}{\theta_0},\ \theta_c = \frac{\bar{\theta}_c}{\theta_0},\ \theta_\infty = \frac{\bar{\theta}_\infty}{\theta_0},\ U = \frac{\bar{U} r_0}{\rho C_p w_0 v_0},\ \bar{U} = \alpha\left(\frac{k_{air}}{\bar{z}}\right)\left(\frac{\rho_{air} v_c \bar{z}}{\eta_{air}}\right)^{\beta},\ E = \frac{\epsilon_m \sigma_{SB} \theta_0^4 r_0}{\rho C_p w_0 v_0 \theta_0}$$

Boundary conditions:

$$v = w = r = \theta = 1, \tau = \tau_0 \qquad \text{at } z=0 \qquad \text{...(6a)}$$

$$\frac{\partial r}{\partial t} + \frac{\partial r}{\partial z}\frac{v}{\sqrt{1+(\partial r/\partial z)^2}} = 0,\ \frac{v}{\sqrt{1+(\partial r/\partial z)^2}} = D_R,\ \theta = \theta_F \qquad \text{at } z=z_F \qquad \text{...(6b)}$$

wherein, r denotes the dimensionless bubble radius, w the dimensionless film thickness, v the dimensionless fluid velocity, t the dimensionless time, z the dimensionless distance coordinate, ΔP the air pressure difference between inside and outside the bubble, B the dimensionless pressure drop, A the air amount inside the bubble, P_a the atmospheric pressure, T_z the dimensionless axial tension, C_{gr} the gravity coefficient, T_{drag} the aerodynamic drag, σ_{surf} the surface tension, θ the dimensionless film temperature, τ the dimensionless stress tensor, D the dimensionless train rate tensor, ε and ξ the PTT model parameters, De the Deborah number, θ_0 the zero-shear viscosity, K the dimensionless activation energy, U the dimensionless heat transfer coefficient, E the

dimensionless radiation coefficient, k_{air} the thermal conductivity of cooling air, ρ_{air} the density of cooling air, η_{air} the viscosity of cooling air, v_c dimensionless cooling air velocity , α and β parameters of heat transfer coefficient relation, θ_c the dimensionless cooling-air temperature, θ_∞ the dimensionless ambient temperature, ε_m the emissivity, σ_{SB} the Stefan-Boltzmamn constant, ρ the density, C_p the heat capacity, D_R the drawdown ratio;

the assumption was made that no deformation occurred in the film past the freezeline at the boundary conditions; overbars denote the dimensional variables; subscripts 0, F and L denote the die exit, the freezeline conditions and the nip roll conditions, respectively; and subscripts 1, 2 and 3 denote the flow direction, normal direction, and circumferential direction, respectively.

2. The method for yielding transient solutions for the film-blowing process by using a film-blowing process model according to claim 1, wherein the non-isothermal process model is a numerical scheme for yielding transient solutions for the film-blowing process, which has three multiplicities.

3. In a nonlinear stabilization analysis method of a process, the improvement comprising that it is an analysis method that utilizes the temporal pictures obtained from the numerical scheme in Claim 1.

4. A method for the optimization of the process which is obtained by use of a sensitivity analysis of the relative effects affecting the stability of each process variable through a transient solution, which was calculated and yielded in the course of deduction of the transient solutions for the film-blowing process in Claim 1.

5. An apparatus necessary for the optimization and stabilization of the process, which utilizes the numerical scheme stated in Claim 1.